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Morphology of the Hypophysis of the Common Goldfish
(*Carassius auratus* L.).¹

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(Plates I & II; Text-figures 1 & 2).

There is much speculation concerning the possibility of pituitary-gonadal relationships in fish similar to those found in mammals. Implants and extracts of fish pituitaries have been found to cause a premature ovulation in fish, (Houssay, 1930, von Ihring, 1935) and an increase in gonad size (Cardoso, 1934). Noble, Kumpf and Billings (1936) have induced brooding behavior in the Jewel fish (*Hemichromis bimaculatus*) with injections not only of fish pituitary extracts but of sheep extracts and prolactin as well. Wunder (1931), Fleischman and Kann (1932), and Kanter (1934), have found the color and ovipositor length of the bitterling (*Rhodeus amarus*) to be affected by hormones from the fish pituitary but not by gonad stimulating hormones from the pituitary of mammals. Smith (1931), Zondek and Krohn (1932), Matthews (1933), Parker (1934), Zondek (1935), Hogben (1936), and numerous other workers have studied the pigmentation effects caused by changes in the amounts of intermedin and other "chromatophorotropic" hormones. The effects of the physiological removal of the pituitary have been observed by Lundstrom and Bard (1932), Matthews (1933), Parker (1935), and Smith, Burr and Ferguson (1935). Recently Abramowitz (1937) has reported the successful removal of the pituitary of the catfish and the killfish, using an opercular approach. Examination of the goldfish gives reason to believe that such an approach would be efficacious in its hypophysectomy. However, an improved technique for this operation, especially one which would make possible a partial ablation, would be highly desirable.

It is the purpose of this investigation to demonstrate the anatomy and histology of the pituitary and its surrounding structures in a form of fish² well adapted to experimentation. *Carassius auratus* (the goldfish) was selected because it is highly adaptable to laboratory conditions and has an exceptional resistance to surgical shock. Also, its compact pituitary is suspended by a stalk which passes through a connective tissue membrane, covering a foramen in the brain-case floor. These protective structures should make it quite feasible to remove the gland without injury to the brain. It is hoped that the observations presented here will provide an adequate foundation for future investigations.

At this time, I wish to acknowledge the thoughtful guidance of Dr. Harry A. Charipper in the accomplishment of this work. I would also like

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² A résumé and key references on the pituitary of various teleosts may be found in the symposium report of H. A. Charipper (1937).

to thank Mr. C. M. Breder, Jr., of the New York Aquarium for providing the laboratory facilities and for his helpful advice on the ichthyological aspects of the problem.

MATERIALS AND METHODS.

The specimens of *Carassius auratus* were obtained from commercial fisheries in Saddle River, New Jersey. Their over-all length varied from seven to eight inches, while their body length from the tip of the snout to the proximal border of the tail fin averaged five inches. Material for histological preparations was fixed between the end of December and the latter part of March. Most of this was from female animals.

For convenience, the fish were removed from the large main tank into small individual tanks before being used. All tanks were supplied with actively flowing tap water, which maintained a temperature of about 8° Centigrade. This water was cold enough to prevent any active maturation of the eggs in the ovaries.

The fish were taken from the water and rapidly anaesthetized by flooding the gills with chloroform. The roof of the cranium was removed first by cutting transversely through the dermal bone between the eyes, and continuing the incision through the dorso-lateral angles of the neurocranium. The entire roof was then lifted and broken away at its posterior margin. The neurocranium was then freed posteriorly by a transverse incision in the region of the medulla, and anteriorly by another incision midway between the olfactory lobes and the olfactory bulbs. Finally the entire neurocranium was separated from the rest of the animal by cutting through the opercular attachments and separating the gill bars from their cartilaginous attachments on the neurocranium. The optic nerves and muscles were carefully cut to avoid altering their relation to the pituitary. The neurocranium with the brain and pituitary were removed to the fixative. The whole procedure was accomplished in about three minutes.

Helly's, Bouin's and Zenker's fluids were employed for fixation. At first the crania from anesthetized fish were immersed in these for about seventeen hours. Later it was found more desirable to kill the animals directly by injecting the fixing fluid through the thin medial wall of the olfactory pit into the cavity above the brain. The neurocranium was then rapidly removed as before and more fluid injected into the myodome near the gland before immersion. The fixation time was reduced to six hours by this procedure.

When the pituitary was to be sectioned alone, it was carefully removed from the cranium after fixation. All attempts to remove the brain and the pituitary together were unsuccessful, due to the fragile nature of the pituitary stalk and to the intimate relation of the endocranial membranes and the bone floor to the pituitary body. Specimens designed for sectioning of the neurocranium were decalcified for four hours in 10% solution of nitric acid in 70% alcohol. Sections of the pituitary were cut from 5-7 micra in thickness and those of the neurocranium at 10-15 micra. Serial sections, longitudinal, horizontal and transverse, were made of the pituitary in situ in the neurocranium and also of the gland alone. The Masson stains were used for cytoplasmic differentiation and Delafield's haematoxylin and eosin as a routine procedure. The latter technique was used for the anatomical preparations.

RELATION OF THE PITUITARY GLAND TO SURROUNDING STRUCTURES.

The pituitary body of *Carassius auratus* lies deeply embedded in the neurocranium. It does not occupy a sella turcica in the basisphenoid bone of the cranial floor as is the case in higher vertebrates. Instead, it lies in a tunnel-like cavity, the myodome, below the floor of the brain case (Plate I,

Fig. 1). This space is enclosed in the apex of the V-shaped neurocranial floor, just above the prominent parasphenoid or "keel bone" (Plate I, Fig. 4). The myodome extends posteriorly from the optic foramina to the region of the medulla, the pituitary lying near its anterior end.

The lateral walls of the teleost neurocranium in the region of the pituitary are formed by the proötic and alisphenoid bones. The alisphenoid bones extend forward and medially to form the walls and floor of the brain case proper in the region of the orbit. Posterior to the pituitary, the roof of the myodome forms the floor of the brain case. This is made up of two horizontal plate-like processes, extending medially from the proötic bones and fusing in the midline, forming the "proötische Brücke" of Holmgren and Stenzio (1936).

When viewed from above, a large oval optic-pituitary foramen may be observed in the floor of the brain case. The posterior rim of this is formed by the proötic bridge and the anterior, more dorsal rim by the alisphenoid bones (Plate I, Fig. 1). Its lateral edges are formed by delicate bony processes projecting from the lateral walls. A thin, tough extension of the endocranial membrane completely covers the foramen except where it surrounds the optic nerves and pituitary stalk as they enter the brain case (Plate I, Fig. 3). A sac-like fold of this membrane is reflected over the pituitary body, which lies immediately below the posterior half of the foramen. The optic nerves enter the myodome through the optic foramina, and then pass through the anterior half of the optic-pituitary foramen to reach the brain.

The pituitary body is placed dorsally in the myodome (Plate I, Fig. 4) above the rectus externus muscles of the eye, which enter this bony chamber ventral to the optic nerves. In transverse section, the muscles appear as two oval masses ventro-lateral to the pituitary. A medial bony septum rises from the parasphenoid a short distance between them.

The pituitary lies with its dorsally flattened surface pressed against the membrane covering the optic-pituitary foramen. Its posterolateral edge is enclosed by a cupping of the rim of the proötic bridge (Plate I, Fig. 3). Likewise the lateral edges of the foramen project past the sides of the gland. (Plate I, Fig. 2). The above three structures effectively separate the pituitary from the cavity of the brain case.

As a result of this separation, the pituitary is suspended from the brain by a short and heavy stalk. This solid process is about twice as wide as it is long in a transverse section (Plate I, Fig. 2). It rises in the midline from the floor of the hypothalamis at the posterior end of the lobus medialis. The latter is a small eminence of the lamina post-optica lying between the anterior ends of two large, oval lateral lobes, the lobi inferior (or mammillary lobes). These latter bodies are over-shadowed dorsally by the larger optic lobes (Plate I, Fig. 4). In a transverse section, the narrow, medial, slit-like cavity of the third ventricle may be seen to penetrate the ventral infundibular region for a short distance but it does not extend into the pituitary stalk.

No large blood vessels were observed entering the pituitary body, although a large vein occupies the angle formed by the posterior indentation of the pars intermedia (Plate I, Fig. 3). The membranes surrounding the gland contain a profusion of small vessels, which were frequently observed to penetrate the pituitary, especially in the region of the pars anterior. The gland, as well as the brain itself, lies in a semi-fluid fatty mass.

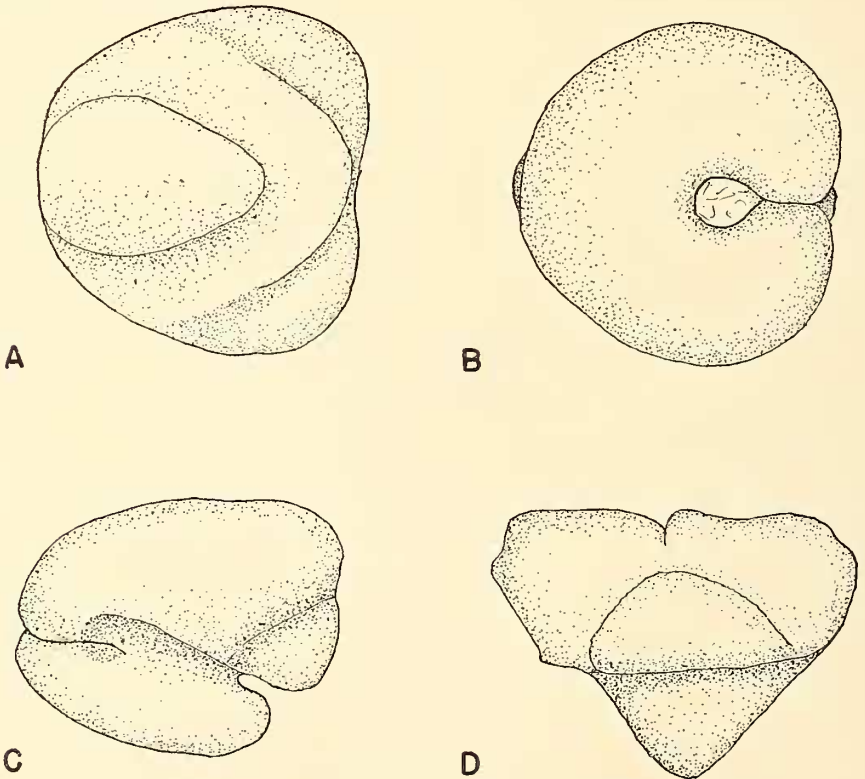
ANATOMY OF THE GLAND.

The pituitary in *Carassius* is an irregular, solid, rounded mass about 1.3 millimeters in length. Its form can best be appreciated by consulting

Text-fig. 1 showing sketches of its various aspects. From above (Text-fig. 1, B) it is almost circular with a flattened posterior side. A slight crevice connects the stalk with the posterior extremity. Ventrally and laterally (Text-fig. 1, A and C), it shows a rounded cone-shaped body projecting from the main mass of the gland. The apex of this cone-like portion of the intermedia points posteriorly and somewhat ventrally. The separation of this portion from the remainder of the pars intermedia is not always so pronounced.

The posterior aspect (Text-fig. 1, D) is almost triangular with the apex being formed by the cone just described. The dorsal, more massive, rectangular portion represents the *übergangsteil* and the remainder of the intermedia. This latter is faintly outlined as a central triangular portion.

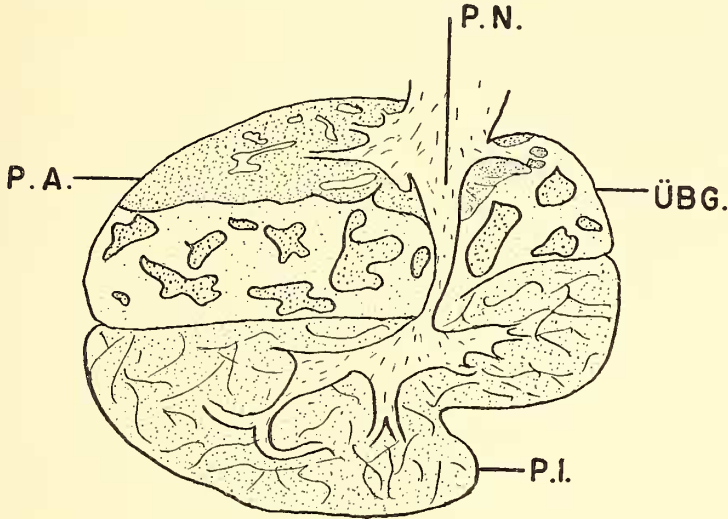
The pars intermedia is the most ventral portion and occupies somewhat less than one-half the volume of the gland. A crevice may be seen to separate this lobe from the *übergangsteil* everywhere except at the very core of the gland. In addition to the cone-shaped, antero-ventral portion the intermedia is made up of a more dorsal plate (Text-fig. 2, and Plate I, Fig. 3), lying intimately in contact with nearly the whole ventral surface of the *übergangsteil*. Anteriorly this plate has a flat dorsal surface, but posterior to the center it rises medially to form a triangular cross section. In some cases the plate disappears entirely from transverse sections taken near the posterior extremity.



Text-figure 1.

Drawings of various aspects of the hypophysis. (A) Ventral aspect, (B) Dorsal aspect, (C) Lateral view and (D) Caudal view. In A, B, and C the nasal end is to the left. Approximately x 12.

The *übergangsteil* is formed by a deep plate of cells, indented anterodorsally by the pars anterior and postero-ventrally by the ridge of the intermedia. The pars nervosa forms a solid core-like mass in this lobe posterior to the midpoint (Text-fig. 2, and Plate I, Fig. 3). Branching root-like processes extended from this into all the other lobes but especially into the pars anterior and the intermedia. A heavy process curves ventrally toward this latter portion in the median plane and on reaching it, broadens out into a mass which sends processes radiating throughout the lobe.



Text-figure 2.

A diagrammatic reconstruction of a median sagittal section of the pituitary body showing the anatomical and area relationships of the various portions. **P.A.**—Pars anterior; **P.N.**—Pars nervosa; **P.I.**—Pars intermedia; **Übg.**—Übergangsteil. Approximately x 15.

The pars anterior (Text-fig. 2, and Plate I, Fig. 3) may be considered to consist of two portions; first, a flat plate-like region anterior to the pituitary stalk and dorsal to the *übergangsteil*—the pars anterior proper; and second, a layer of peculiar cells enveloping the dorsal nervosa mass and the roots of the processes which radiate from it (Plate I, Fig. 5).

HISTOLOGY OF THE PITUITARY GLAND.

Pars Nervosa. This tissue appears as a loose fibrous mass with scattered neuroglia nuclei and occasional glandular cells (Plate I, Figs. 2, 3, 5). The coarse basophilic fibers run lengthwise in the cords, as do the nuclei of the neuroglia cells. These latter are fusiform or irregularly elongate in shape and are characterized by scattered coarse granules. They are stained red with the Masson technique. Occasionally an area appears around the nuclei which stains as would cytoplasm, but no cell borders are visible. Numerous large basophilic glandular cells, resembling those of the *übergangsteil*, are found in the nervosa masses but not in the cords. These are always degenerate and often appear as irregular blue masses. Eosinophilic colloid material was observed in rare cases only. Numerous blood vessels penetrate the cords of the nervosa and occasional large vessels appear in the dorsal mass.

Pars Intermedia. A compact irregular cord-like arrangement is characteristic of the pars intermedia (Plate I, Fig. 6). The cords are separated from each other and from the processes of the nervosa by thin connective tissue membranes. The lobe appears as a typical epithelial gland, and the roots of the nervosa occupy only a small portion of its volume.

Two cell types were observed—a large, rounded one, flattened by adjoining cells, and a smaller, more polygonal type (Plate II, Fig. 7). The rounded cells are predominant and are responsible for the faintly basophilic staining reaction of this lobe. They occupy the center of the cords and much of the periphery, while the polygonal cells are always located adjacent to the connective tissue membrane.

The vesicular nuclei of the basophils are large and oval and occasionally indented. They are made prominent with the Masson stains, by a deep red-staining rim, scattered large red granules, and often a round, central nucleolus. The cytoplasm is marked by numerous faint blue granules.

The polygonal cells are smaller than the basophils, although their nuclei are identical in size as well as staining reaction. The cytoplasm of the former is dense and finely granular. It takes both acid and basic stains better than that of the basophilic cells and stains a reddish purple with the Masson technique. These may be called amphiphils.

The goldfish intermedia is moderately well supplied with blood vessels. The largest vessel observed in the pituitary appears in the region adjacent to the lower nervosa mass (Plate I, Fig. 3). Numerous other smaller vessels are associated with the connective tissue elements throughout the intermedia and between this lobe and the *übergangsteil*.

Übergangsteil. The *übergangsteil* is the largest portion of the pituitary body, occupying about one-half of its volume (Plate I, Fig. 3). Although connective membranes separate it from the pars intermedia and the pars nervosa, no similar structure lies between its cells and those of the pars anterior. The *übergangsteil* is quite homogeneous in structure; there are no connective tissue elements within it and nervosa processes extend into it for only a short distance. Strongly contrasting areas appear, however, as a result of differential staining. Small irregular masses of deep-staining acidophils are characteristically distributed throughout a deeply basophilic background (Plate I, Fig. 3, and Plate II, Fig. 8). These masses increase somewhat in number, as one proceeds posteriorly. The transition from acidophilic to basophilic areas is strikingly sharp and is visible even in unstained sections.

The acidophilic areas (Plate II, Fig. 8) are made up of large, polygonal cells, having a finely granular cytoplasm, which takes an intense red color with the Masson stains. The cell borders are exceptionally sharp and distinct while the nuclei are very prominent and about the size of those of the pars intermedia. The round or oval vesicular nuclei possess a few large granules and frequently a large central nucleolus. Like the nuclei of the intermedia, these take a deep red stain and have a dense rim. Scattered among the acidophils are occasional polygonal cells with the typical red nuclei but whose cytoplasm is vesicular, containing large faintly violet granules. These are chromophobic cells, presumably degranulated eosinophils.

The basophilic background (Plate II, Fig. 8) is composed of large polygonal cells, having indistinct borders and spherical or picnotic nuclei, that are more granular than those of the acidophils. The nuclei of most of the cells appear degenerate and many are missing entirely. With the Masson stains, several differentiated areas may be distinguished. The cells of all regions possess large red cytoplasmic globules which are usually located near the cell borders. The cells of the central region have relatively few globules in a pure blue cytoplasm in which individual granules cannot be

distinguished. Those of the posterior region are similar but have more numerous globules. The most anterior region and also an area of cells lying below the pars anterior present a different picture. Here the number of globules is greatly increased so that they may occupy a large portion of the volume of the cells. The cytoplasm is not deep blue but shows a coarse violet or violet and blue granulation. These cells appear to be largely degranulated although they have not lost their red globules.

The vascular supply of the *übergangsteil* is poor. Only small capillaries have been observed, and rarely do more than several of these appear in any one field.

Pars Anterior. The characteristic cellular arrangement in the pars anterior is due to the presence of a large number of cords of the nervosa which course through the lobe in an anterior-posterior direction (Plate I, Fig. 5, and Plate II, Figs. 10, 11). In tranverse section, the lobe has a perforated appearance, while in a sagittal section, the cells seem to be divided into horizontal cords several cells in depth.

The cells are small as compared with those of the *übergangsteil* and the *intermedia* (Plate II, Figs. 9, 10). They are rounded or polygonal and have distinct borders and large typically ovoid nuclei. Many indented or folded nuclei are also present. The majority of the nuclei are vesicular, having large, deep red granules and a smooth prominent red rim outlined against a yellowish nucleoplasm. On the basis of cytoplasmic staining reactions, three cell types may be distinguished; e.g., purplish-red amphiphilic cells, basophils, and chromophobes. The lobe is composed predominantly of the amphiphils, which have considerably less affinity for acid fuchsin than the amphiphils of the *pars intermedia*. The chromophobes (Plate II, Fig. 10) are relatively scarce and are distributed uniformly throughout the lobe. They have normal nuclei but appear pale violet in color like the degranulated cells of the *übergangsteil*. The basophils (Plate II, Fig. 10) are smaller than the other cells but have nuclei which are identical in size and staining reaction. Their cytoplasm is filled with fine deep blue granules.

A transition from a predominantly basophilic condition next to the *übergangsteil* to an acidophilic one at the dorsal free border, occurs in this lobe. Most of this is due to the depth of staining of the amphiphilic cells. At the ventral border, the majority of these assume a deep purple color and have a dense cytoplasm without visible granulation, while those at the dorsal border are more red than purple and have varying numbers of coarse granules. Some of the transition is also due to the increase in the number of basophils toward the ventral border. At most, however, these cells account for only a small fraction of the change.

A few of the amphiphilic cells possess nuclei unlike the vesicular acidophilic nuclei of the remainder of the cells of the pars anterior. They are uniformly filled with fine basophilic granules, are without nucleoli, and have a deep blue rim (Plate II, Fig. 9).

The processes of the nervosa that penetrate the pars anterior are highly fibrous and especially loose in consistency (Plate II, Figs. 10, 11). Associated with most of them are blood vessels of various sizes; these always lie within the connective tissue membranes separating the processes from the surrounding cells (Plate II, Fig. 11). A few vessels lie in the parenchyma itself, and occasionally one of these near the free border may be seen to connect with a vessel in the connective tissue capsule of the gland. The pars anterior is the most vascular lobe of the goldfish pituitary; nevertheless, its vascular supply is relatively poor as compared with that lobe in the mammal and most higher vertebrates.

The layer of cells, enveloping the dorsal mass of the pars nervosa (Plate I, Fig. 5) is considered part of the pars anterior, because of their resemblance to the cells found in that part of the gland and should be

confirmed further by morphogenic studies. The layer is thickest next to the mass and thins down to a few cells as it follows the processes a short way. Some nesting of the cells is evident. A few cells follow the main stalk all the way to the pars intermedia. The cells are small and polygonal with large vesicular nuclei and a scanty rim of cytoplasm. When stained with Delafield's hematoxylin and eosin, the nuclei are deep blue and the cytoplasm is a faint blue. Masson staining produces a pale violet coloration of the fine cytoplasmic granules. The nuclei are pale yellowish-red with deep red rims and a few scattered large red granules.

DISCUSSION.

The anatomical relationships of the pituitary in *Carassius auratus* to the neurocranium and brain resemble those found in higher vertebrates more than in most other teleosts. Matthews (1936) found the pituitary of *Fundulus heteroclitus* to be closely applied to the floor of the brain and merely covered ventrally by the parasphenoid bone. This condition is characteristic of most of the teleost pituitaries that have been described, e.g., *Anguilla vulgaris* and the Mormyridae (Stendell, 1914), *Anguilla anguilla* (Florentin and Weiss, 1931, and v. Hallerstein, 1934), *Gasterosteus aculeatus* (Bock, 1928), *Gadus morrhua* (Herring, 1908 and 1913) and the haddock (de Beer, 1926).

In *Carassius*, on the other hand, the gland is separated from the brain by the shelf-like cranial floor and the extension of the endocranial membrane over the optic-pituitary foramen. As a result of this change, the pituitary is attached to the lobus medialis by a relatively long stalk, which penetrates the foramen. Two teleost pituitaries, those of *Cyprinus carpio*, the carp, and of *Esox lucius*, the pike, as described by Stendell (1914), are very similar in structure to the gland of the goldfish. Whether they also have similar anatomic relationships is unknown. In fact, previous accounts of teleost pituitaries have included only brief comments on this subject. The only available literature dealing with it is that provided in anatomical discussions by Jordan (1905), Gregory (1933), von Hallerstein (1934) and Holmgren and Stenzio (1936).

Four main divisions were differentiated in the goldfish pituitary: pars nervosa, pars intermedia, übergangsteil, and pars anterior. These terms have been used by de Beer (1926) and other recent workers in describing the teleost pituitary. The configuration and structure of these divisions show a marked similarity to those in *Esox* and especially in *Cyprinus*.

Certain changes in the orientation of the various lobes have taken place as a result of the development of the pituitary stalk. The glands have assumed a compact ovoid form with a somewhat variable orientation of the lobes. The pars anterior of *Carassius* and *Esox* are antero-dorsal in position while the pars intermedia is ventral and ventro-caudal respectively. In the acorn-shaped gland in *Cyprinus*, the pars anterior is dorsal and the intermedia is directed antero-ventrally. The change in the position of the gland in *Cyprinus* has been associated by Stendell (1914) with its greater anterior rotation as a result of a more extensive stalk formation. These glands represent a considerable advance over the condition in other teleosts, in which the lobes are serially extended in an anterior-posterior direction, i.e., pars anterior, übergangsteil, and pars intermedia.

The goldfish has a typical teleost pars nervosa, which is composed of a mass of tissue in the postero-dorsal region, from which root-like processes radiate in all directions into the glandular tissue. Like *Cyprinus*, however, it has an additional long internal process leading to the distant, compact, lobe-like pars intermedia. Here the process ends in an additional mass of nervosa tissue from which processes radiate throughout the intermedia. The fine structure of the nervosa is very similar to that described by other work-

ers. Numerous acidophilic colloid droplets have been noted in the nervosa adjacent to the pars intermedia by Herring (1908), Stendell (1914), Bock (1928), and Matthews (1936). Some such strongly acidophilic material was observed in the pars intermedia and occasionally in the adjacent nervosa in *Carassius*. This material was missing, however, in the dorsal mass of the nervosa. Stendell (1914) and Bock (1928) noted glandular cells distributed throughout the nervosa and stated that these had migrated there from the pars intermedia and the pars anterior. These cells are present in *Carassius* but they definitely resemble the basophils of the *übergangsteil*.

The pars intermedia of the goldfish forms a distinct lobe and, like that of the carp, it is separated from the *übergangsteil* by a partial cleft and a connective tissue membrane. In most other teleosts it consists of a region, occupying the posterior or postero-ventral extremity and enveloping the roots of the nervosa. This is the case in *Anguilla*, *Mormyrus*, *Mugil*, *Salmo*, *Chrysoops* and *Esox* (Stendell, 1914) and in *Gasterosteus* (Bock, 1928). In *Fundulus* it takes the form of a layer, several cells in thickness, following the contours of the nervosa (Matthews, 1936).

Stendell (1914) found no pattern of cell arrangement and no blood vessels in the intermedia of the teleosts he studied. The only vascular supply in this lobe was that carried into it by the roots of the nervosa. The condition is strikingly different in *Carassius*. Here the parenchyma is broken up into irregular cords by a connective tissue network which extends throughout the lobe. Moreover, blood vessels are more numerous in this lobe than are free in the parenchyma of all the pituitary regions. The cord-like arrangement resembles that seen in the intermedia of some of the mammals.

As in all vertebrates, the intermedia of the goldfish is predominantly basophilic in staining reaction. The cells in the center of the cords are basophilic while many of those next to the nervosa and connective membranes are amphiphilic in reaction. The latter take both acid and basic stains better than the basophilic cells. Matthews (1936) noted large intensely staining acidophiles adjacent to the nervosa cords in *Fundulus* and Stendell found a similar condition in *Esox*. It seems likely that these cells are identical with the amphiphils in *Carassius*. As in Matthews' description in *Fundulus*, many of the nuclei in this lobe of the goldfish pituitary are folded or indented.

A marked similarity also exists between the *übergangsteil* of *Carassius* and that of *Cyprinus* (Stendell, 1914). In both it is the largest portion of the complex; that of *Carassius* is central in position while it is central and posterior in *Cyprinus*. The position of this lobe in other teleosts is highly variable. The simple pituitaries, lacking hypophyseal stalks, have a mass of differentiated cells occupying a central position between the pars anterior and the pars intermedia. Bock (1928) found it to be located centrally in *Gasterosteus* and to be covered ventrally by the pars anterior and the pars intermedia. In *Esox*, it is a compact mass in the anterior region while in *Fundulus* (Matthews, 1936), it is composed of an anterior mass and a layer which covers the periphery of the gland everywhere except at the posterior extremity.

Many irregular patches of large polygonal acidophils lying in a background of similar basophilic cells have been described in the *übergangsteil* of the goldfish. Stendell (1914) found acinar groups of acidophils lying in a chromophobic background in the closely related *Cyprinus* and in a basophilic area in *Esox*. The basophils of the goldfish appear degenerate, at least in the late Winter and Spring, but nevertheless they take a much stronger basophilic stain than the basophils of the intermedia.

The staining reactions of the *übergangsteil* of the various other teleost pituitaries are variable and widely divergent from these. Tilney (1911) described columns of acidophils, separated by blood vessels in *Anguilla vulgaris*, while Stendell (1914) found the cells to be predominantly basophilic in this

form and in *Mormyrus*. This lobe is predominantly acidophilic in *Fundulus* (Matthews, 1936) and *Gadus* (Herring, 1908) and equally acidophilic and basophilic in *Esox* (Stendell, 1914). Usually the cells of the other teleost übergangsteils are smaller and more rounded than those of *Cyprinus*, *Esox* and *Carassius*.

Stendell (1914) held that there is a progressive increase in the number of basophils and a decrease in acidophils from the region adjacent to the pars anterior to that next to the pars intermedia in the teleost übergangsteil. Bock (1928) could not confirm this in *Gasterosteus* nor does it occur in *Carassius*. In the latter, an increase in the number of acidophilic masses occurs toward the caudal extremity.

Few nervosa cords penetrate the teleost übergangsteil. Connective tissue has not been reported in it, and there is no sharp boundary separating it from the pars anterior. In *Gasterosteus* there is a partial separation (Bock, 1928).

A pars anterior, very similar to that described by Stendell (1914) in *Cyprinus* and *Esox*, is present in *Carassius*. Matthews (1936) was unable to distinguish such a differentiated portion in *Fundulus*. However, all other descriptions in teleosts have included such a portion in an anterior or antero-dorsal region of the pituitary.

A characteristic cellular arrangement in the form of cords, separated by processes of the nervosa was noted in *Carassius*. Stendell (1914) noted a similar cord-like arrangement of the cells in *Cyprinus* and *Esox*, but found them to be separated by blood sinusoids. Many large blood vessels were found enclosed within the nervosa cords in the goldfish and it seems possible that Stendell mistook such cords for blood sinuses.

Most of the cells of the goldfish pars anterior stain purple or a purplish-red with the Masson stains and have been described as amphiphilic. Some basophils and chromophobes are also present. The cells of *Cyprinus* and *Esox* (Stendell, 1914) and *Anguilla vulgaris* (Tilney, 1911) are reported to be basophilic. Stendell (1914) also described large acidophils next to the blood sinusoids in *Esox*. He and Bock (1928) have found the pars anterior to be acidophilic in the primitive *Mormyrus* and *Gasterosteus*, respectively. It is interesting to note that an antero-dorsal chromophobic zone was found in the pars anterior of *Gasterosteus* (Bock, 1928) and in *Gadus morrhua* (Herring, 1908). In the former, the nuclei are closely packed and surrounded by a small ring of basophilic granules.

A small specialized region has been included in the discussion of the pars anterior of *Carassius* although its significance is uncertain. This is the area of small polygonal cells surrounding the pars nervosa and fusing with the posterior end of the pars anterior proper. The cells resemble those of the pars anterior in size but have less cytoplasm and are nearly chromophobic. On the other hand, its position and form, as a layer surrounding the nervosa, immediately recalls the descriptions of the pars intermedia in *Fundulus* (Matthews, 1936), in the haddock and the cod (Butcher, 1936) and in other teleosts. It seemed advisable to classify this region with one of the other lobes of the gland until more is known about it rather than further confuse the pituitary terminology.

No large blood vessels were found entering the pituitary body in *Carassius*. Occasionally capillaries were observed, however, leaving the rich network in the pituitary capsule and entering the pars anterior. The blood supply of the gland is poor as compared with those of most higher vertebrates; this is true in general of all teleosts. The pars anterior is most vascular of the teleost lobes with the exception of that in *Gasterosteus* (Bock, 1928). In *Carassius*, the vessels are located in the nervosa cords while in *Anguilla* (Tilney, 1911) and *Esox* and *Cyprinus* (Stendell, 1914) numerous blood sinusoids are reported. The pars nervosa carries numerous vessels

throughout the gland. Few vessels are present in the *übergangsteil* in *Carassius*, *Anguilla* and *Cyprinus* (Stendell, 1914) while *Mormyrus*, and *Esox* (Stendell, 1914) and *Fundulus* (Matthews, 1936) are somewhat better supplied. Blood vessels are reportedly absent in the parenchyma of the *pars intermedia*, nevertheless they are present in considerable number in *Carassius*.

In the accounts of the pituitary of the teleosts, most investigators have included a thin-walled, folded pouch, the *saccus vasculosus*. This lies posterior to the gland and is a separate outgrowth of the posterior hypothalamus. It is not present in all Teleostei; von Hallerstein (1934) reported the presence of one in *Cyprinus* but there is none in *Carassius*. The *saccus vasculosus* is related in no way to the pituitary body. According to von Hallerstein (1934), its thin epithelial wall contains numerous characteristic sensory cells, as well as nerves, which is evidence for its being a special sense organ. For these reasons, it is suggested that this organ should be omitted from discussions of the teleost pituitary.

If granulation and regranulation, as evidenced by the presence of the similar cells with varying numbers of granules can be taken as evidence of secretory activity, as is usually done, and if certain changes in the form and staining reaction of the nuclei may also be taken as such evidence (as Severinghaus (1938) believes valid for the rat at least) then the cells of the pituitary of the goldfish may be considered to be in a state of active secretion in the late Winter and early Spring. Such variations in granulation occur in *Carassius* both in the *pars anterior* and in the *übergangsteil*. Scattered about the *pars anterior*, cells have been observed the nuclei of which stain uniformly with basic stains instead of the usual vesicular manner with acid ones. Otherwise these cells cannot be differentiated from the normal amphiphilic cells.

In this discussion of the pituitary, the terminology developed by Stendell (1914), Herring (1908), Tilney (1911) and de Beer (1926) and used as such by de Beer, has been adopted. This is based on Stendell's homology of the various portions of the teleost pituitary with those of this gland in higher vertebrates. The suitability of this terminology has been questioned. Indeed, Stendell himself stated that the *übergangsteil* of the Teleostei suggests the *pars anterior* more than it does the *pars intermedia*. He thought it not impossible that the anterior lobe of higher vertebrates arose from the *übergangsteil* of fish.

Bock (1928) carried this idea to a positive conclusion as a result of his study in *Gasterosteus*. He said that the anterior lobe of Teleostei is thus to be regarded as a structure typical of this group, to which there is no homology in amniotes and amphibia.

In the absence of detailed embryological evidence Stendell, (1914), preferred to retain a homology based largely on relative position. It seems to the author, however, that a modification of this type of "homology" to include histological and cytological similarities, such as Bock (1928) suggested with respect to the *übergangsteil*, would be of definite value. Such a homology would undoubtedly approach closer to a fundamental physiological analogy. Such an analogy and the simplification it might bring should be the goal of comparative physiological experimentation. Very little has been accomplished in this direction as yet, with the exception of the work on the *pars intermedia*. The functions of the other portions of the pituitary in vertebrates below the mammals are almost completely unknown.

Both the evidence of secretory activity and the cytological structure of the cells of the *pars anterior* and the *übergangsteil* in the goldfish pituitary, suggest that these two portions ought to be considered as a glandular complex, which is equivalent to the *pars anterior* of higher vertebrates. Although no attempt has been made here to study the embryological origin of

the various portions and thus arrive at a true homology, if such a thing is possible, the lack of separation of the *übergangsteil* from the *pars anterior* suggests a common embryological origin. In contrast to this, there is a very definite separation of the *übergangsteil* from the *pars intermedia*.

The *pars anterior* (*Hauptlappen*) in teleosts was considered by Stendell (1914) to be homologous to the lobe of that name in higher forms, while Bock (1928) thought it was distinctive of this group. Certain facts suggest another possibility, which would afford a definite simplification in terminology. This lobe is strikingly similar to the *pars tuberalis* in reptiles, birds and mammals in various morphological respects. The lobe is typically composed of small polygonal basophils with a few acidophils in some forms. Only the primitive pituitaries of *Mormyrus* and *Gasterosteus* are acidophilic. The acinar, vesicular, cord-like or columnar arrangement of the cells found in the *tuberalis* of various higher vertebrates can all be duplicated in the teleost *pars anterior*. Stendell (1914) has reported the presence of intercellular colloid in *Esox lucius*.

The position and relationships of the *pars anterior* may also be equated to the *tuberalis*. It is dorsal or antero-dorsal in the more complex teleost pituitaries and anterior in the lower forms. The position of the *pars tuberalis* in amphibians is antero-ventral, in reptiles it is antero-dorsal, and in birds and mammals it is dorsal. The *tuberalis* usually fuses with the *pars anterior* without a line of separation much as the teleost *pars anterior* does with the *übergangsteil*. In the stalked pituitaries, the *pars anterior* lies in contact with the infundibular stalk much as does the *tuberalis* in the birds and mammals.

It seems desirable to simplify the pituitary terminology in the teleosts and to correlate it with that applied to higher vertebrates. The morphological similarity of the teleost *übergangsteil* and *pars anterior* with the *pars anterior* and *pars tuberalis* respectively of higher forms suggests that the latter terms might well be substituted for the former in referring to the teleost.

No thorough cytological investigation has been attempted in this paper. An elaboration of this material with information of that type, secured throughout the year and including seasonal variations would allow a more critical examination of the above question. At best, however, this can only elaborate on the morphological similarities. By combining this method with physiological experiments, an analogy with the functions of the lobes of the pituitary of higher vertebrates might be established.

SUMMARY.

1. The anatomical relationship and position of the pituitary gland in the teleost fish, *Carassius auratus*, are distinctive not only in the vertebrate group as a whole but also in the teleost group itself. It is well below the floor of the brain in the region of the diencephalon, above the prominent parasphenoid and surrounded by the proötic and alisphenoid bones. Its dorsal surface is separated from the floor of the brain by a tough membrane.
2. The pituitary body is attached to the brain in the infundibular region of the hypothalamus by a cylindrical stalk, which penetrates this membrane.
3. Only a few small blood vessels were observed entering the gland from the vascular network in its connective tissue sac. As in most teleosts the gland is poorly vascularized as compared with those of higher vertebrates.
4. The pituitary is made up of the following four main divisions.
(A) A *pars nervosa* made up of two irregular masses connected by a

heavy process. Root-like processes ramify throughout the pituitary from these regions.

(B) A pars intermedia which is a large compact ventral lobe almost completely separated from the übergangsteil by a narrow cleft.

(C) An übergangsteil in the form of a large thick plate-like region dorsal to the pars intermedia. Its structure resembles most closely the pars anterior of higher vertebrates.

(D) A small plate-like pars anterior in the antero-dorsal region. In structure it is very similar to the pars tuberalis of many of the higher vertebrates.

5. Evidence is offered to confirm Bock (1928) in the suggestion that the übergangsteil in Teleostei is really the pars anterior in the sense that this term has been applied to higher vertebrates.
6. Similarly evidence is presented and the suggestion is made that the "pars anterior" in Teleostei is in fact the pars tuberalis of higher forms. Cell type, arrangement, and the position and relationships of the lobe as a whole were used as criteria.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Median sagittal section of a portion of the neurocranium with the brain and pituitary in situ. Nasal end at the right. The section shows the pituitary (**P**) lying in the myodome (**MY**) below the floor of the brain case. The cerebrum (**CB**), cerebellum (**CBL**), lobus viscerosensibilis (**L.V.S**), parasphenoid (**PS**) and optic nerve (**O.V.**) are also indicated. Zenker's; Delafield's haematoxylin-eosin. x 4.
- Fig. 2. Transverse section of the pituitary near the posterior end and of adjacent structures, further magnified from Fig. 4. Note the cavity of the third ventricle above the pituitary stalk and the thin lateral bone shelves between the gland and the brain. **P.N.**, pars nervosa; **UBG**, Übergangsteil; **P.I.**, pars intermedia. x 13.
- Fig. 3. An area from Fig. 1 under higher magnification, showing the attachment of the pituitary to the brain, the cupped anterior rim of the proötic bridge, the connective tissue capsule of the gland, and the large blood vessel lying in the posterior indentation of the intermedia. Nasal end at the right. **P.A.**, pars anterior. x 13.
- Fig. 4. Transverse section of a portion of the neurocranium with the brain and pituitary in situ. The section shows the attachment of the pituitary to the floor of the hypothalamus and the bony shelves that separate them laterally. **B.S.**, bony shelf; **L.In.**, lobus interior; **L.M.**, lobus medialis; **O.L.**, optic lobe; **P.**, pituitary; **R.M.**, rectus muscle. Bouin's; Delafield's haematoxylin-eosin. x 4.
- Fig. 5. Dorsal mass of the pars nervosa and the adjacent specialized region of the pars anterior (the group of cells above the arrows). The dark cells in the nervosa are glandular cells similar to the basophils of the Übergangsteil. Zenker's; Masson stains. x 160.
- Fig. 6. Transverse section of epithelial portions of the pituitary showing histological structure of the (**P.I.**) pars intermedia; (**UBG**) Übergangsteil and (**P.A.**) pars anterior. The dark areas in the Übergangsteil represent acidophils and the light areas in the pars anterior are nervosa cords. Zenker's; Masson stains. x 200.

PLATE II.

- Fig. 7. Pars intermedia showing amphiphilic cells adjacent to the nervosa cord at left. Remaining cells are weakly basophilic. Zenker's; Masson stains. x 1080.
- Fig. 8. Übergangsteil area. Acidophils appear dark while the basophils appear chromophobic with haematoxylin. Several chromophobes may be noted among the acidophils. Bouin's; Delafield's haematoxylin and Masson A. x 1800.
- Fig. 9. Pars anterior at the dorsal border, showing typical amphiphilic cells, three with dark basophilic nuclei, also occasional chromophobes. Zenker's; Masson stains. x 1800.
- Fig. 10. Pars anterior near the ventral border with deeper-staining amphiphils than in the more dorsal region. **C.**, chromophobe; **B.**, basophil; **A.**, amphiphil. Zenker's; Masson stains. x 1800.
- Fig. 11. Section of an area from the pars anterior showing cords of the nervosa with blood vessels typically enclosed within them. Zenker's; Masson stains. x 1800.